SOLID WASTE & WASTEWATER MANAGEMENT
FOR THE TOURISM INDUSTRY

MODULE 6

AN INTRODUCTION TO WASTEWATER MANAGEMENT

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OBJECTIVES:

- To provide an overview of the sources and characteristics of wastewater in the Caribbean.
- To outline the impacts of wastewater and potential impacts from the perspective of the tourism industry.
- To introduce wastewater treatment methods and recommendations to the tourism industry.

OVERVIEW:

- Wastewater constitutes the major sources of land-based pollution into the marine environment and a significant threat to coastal ecosystems on which Caribbean tourist- based economies depend.
- Domestic wastewater is generally poorly treated in the region as there are very few treatment plants in good operating condition.
- Major impacts include human-health risks to locals and visitors, fisheries depletion and aesthetically unpleasant bathing waters.

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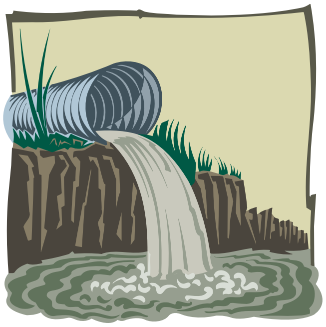
INTRODUCTION

The increased supply of potable water together with the growing standard of living and increased industrialisation in the Caribbean, including tourism, has resulted in more and more wastewater to be disposed of. Considerable attention is therefore now being paid to wastewater in nearly all Caribbean countries. This follows the realisation that wastewater constitutes the major source of land based pollution of the marine environment and is a significant threat to the integrity of the fragile ecosystem on whose survival the tourist-based economies depend.



The accelerated growth of population and industrialization in many countries together with inadequate water, wastewater and environmental resource management, provide indiscriminate pollution to rivers, estuaries, lagoons and marine ecosystems and directly to fresh water resources.

Sources & Characteristics Of Wastewater

Wastewater is usually classified as industrial wastewater, storm, or domestic wastewater. Characteristics of industrial wastewater vary greatly from industry to industry, and consequently, treatment processes for industrial wastewater also varies, although many of the processes used to treat municipal wastewater are also used in industrial wastewater treatment. Water collected in municipal wastewater systems contain a wide variety of contaminants. These contaminants can vary in quantity and with time (e.g. daily or seasonally).

The most significant components of wastewater are usually suspended solids, biodegradable organics, and pathogens. Suspended solids are composed of some of the more objectionable materials in sewage such as body waste, food waste, paper, and rags. Removal of suspended solids is therefore essential prior to discharge or reuse of wastewater.

All forms of waterborne pathogens can be found in domestic wastewater. Usually a sufficient number of pathogens are present in all untreated wastewater and represent a substantial health hazard.

Domestic Wastewater

There is a general absence in the Caribbean region of wastewater treatment plants which are in good operating condition. Virtually all municipal sewage is discharged into the nearest rivers, streams, or marine environment, most times with inadequate treatment. This results in infection by pathogenic organisms, of these environments. Although domestic sewage is mainly biodegradable, the input of sewage into the environment in many locations in the Caribbean exceeds the natural regeneration and dispersal capacity of the recipient water bodies. The result is a significant degradation of the quality of water.

The most widely used system of sewage disposal is the septic tank and soakaway, and in the coral islands, like Barbados, the suck well, which is a deep pit to facilitate percolation of the wastewater discharged. In areas where soil conditions do not permit proper infiltration, effluent is generally disposed of in street drains, e.g. in Antigua.

Sewer systems exist in many Caribbean countries. Many old sewer systems discharge without prior treatment into rivers or the marine environment while most new sewer projects incorporate treatment to some extent before disposal.

Industrial Wastewater

The process of industrialization in the Caribbean has contributed to the increased occurrence of water pollution. In many countries, practically all the most toxic industrial effluent is discharged into the nearest water bodies without adequate treatment.

Industrial wastewater in the Caribbean may contain heavy metals, various toxic substances, oil and fat, colour and turbidity, suspended solids, and other substances. Many of their components are resident to biodegradation.

The major industrial waste loads in the region are generated by inter-alia, chemicals and petrochemicals and petroleum refining, metal working, and food processing (including sugar).

Food processing industries are also important dischargers of pollutants, for example, brewery wastes, dairy wastes, and poultry processing. The sugar refining industry (e.g. Trinidad) and the distilling and rum industries (e.g. Barbados, Jamaica) also produce strong organic waste.

Non-point Source of Pollution

Storm-water run-off can be significant in the Caribbean, as much of the region lies in the tropical zones characterized by heavy rainfall. Storm-water runoff has been cited by the Caribbean Environmental Health Institute (CEHI) as a possible source of coastal pollution from oil storage depots, gas stations, generating plants, ships, waste disposal sites and factories in Dominica, Grenada and St. Vincent.

IMPACTS OF WASTEWATER

The tourism industry can be seriously affected by wastewater and can also be a significant contributor of wastewater to the environment. It is, therefore, critical that this industry pay careful attention to wastewater issues.

Numerous environmental studies done in the region have established that there is serious pollution of rivers and streams as well as the coastal and marine environments from wastewater resulting in health risks, depletion of fisheries, and the destruction of marine ecosystems.

Health Impacts

Contaminated drinking water and inadequate disposal of sewage and excreta are among the three leading causes of disease and death in the world. There are a wide variety of diseases related to wastewater, especially when wastewater is polluting drinking water reservoirs. Sewage and excreta seriously threaten public health because they have high levels of pathogenic organisms and other toxic substances. These pathogenic organisms pose the greatest risk.

Many diseases, like cholera, typhoid, yellow fever, and infectious hepatitis have been attributed to contamination of well-water by improper sanitation and wastewater disposal.

Several highly significant diseases in terms of both public health and the economy are closely linked to poor sanitation, inappropriate excreta disposal, and lack of personal hygiene.

Water-borne epidemics have been known to occur in the region as well as water-washed diseases such as scabies and conjunctivitis, and water-associated diseases such as schistosomiasis and dengue.

Groundwater pollution from poorly-constructed septic tanks, pit latrines and soakaways is a major concern in some of the smaller islands in the region, specially those which depend exclusively on groundwater for their drinking water supply.

Very few cities in the Caribbean treat municipal waste before discharging it into the ocean and the treatment is often inadequate to prevent biological contamination. The same is true for many hotels in the Caribbean. Very often, untreated or poorly treated sewage is discharged into rivers, streams, and drains which empty into the ocean, or it is discharged directly into the ocean through a short outlet. Many beaches close to urban centres and hotels are polluted with fecal coliforms and viruses.

While coastal and marine waters are generally not used for drinking purposes (with the exception of the Reverse Osmosis Process), sanitary quality of these waters relate to the use of these waters, e.g. bathing and water sports, and harvesting of fish and shell fish. Skin rashes can be attributed to bathing in or with polluted water. Ear, nose, and throat infections and sore eyes could also result from bathing in polluted waters.

> Given the importance of tourism in many countries of the region, the pollution of beaches is a matter of concern.

Bathing in turbid waters is generally regarded as unappealing and could pose physical health risk when visibility prevents the bathers from seeing possible objects (rocks or debris) on the bottom.

Information is scant on actual health effects associated with bathing in polluted recreational waters in the Caribbean. However, work is being conducted by the Institute of Marine Affairs (IMA) in Trinidad, specifically to address this problem.

There are also requirements for holding tanks in yachts in many areas in the Caribbean which discharge sewage directly into marinas and other anchorages. Recreational waters are therefore subject to pollution from this source as well.

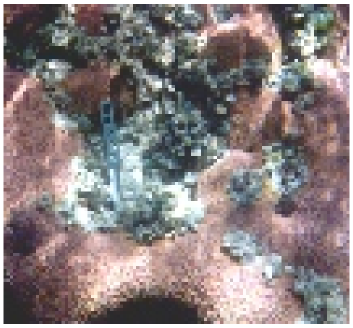
Environmental Impacts

Disposal of raw or primary treated effluent can result in smells, floating matter, scum and turbid waters. It is known that after the sudden growth of phyto-plankton ("algal blooms") massive sudden die offs can occur. Underlying organisms will be blanketed and suffocated and the biological breakdown of this dead material can cause a stench and unsightly black residues. Algal blooms can turn the water into a thick green viscous liquid. This will of course drastically restrict sunlight penetration. In the tourism sector, these conditions will surely have a negative impact.

Nutrient-rich wastewater will disrupt most of the very fragile ecosystems in the Caribbean and could destroy coral reefs, seagrass beds, beaches, fish and endangered species. In actual fact, the discharge and infiltration of nutrients from untreated wastewater has been damaging and eroding coral reefs and destroying fisheries in Caribbean countries for many years.

Death of the coral reefs and the related erosion of beaches have been described by many authors as caused by the discharge of sewage. Coral reefs can be affected in many ways. Primary pollution, reducing the oxygen level and increasing the turbidity, will reduce their metabolism.

Mangroves are used by fish as breeding grounds and by their nature, mangrove swamps act as natural filters of land drainage. Changes in nutrient levels can affect this ecosystem.



Coral heads in a back reef lagoon showing signs of partial death and recolonisation by algae

Wastewater disposal in the tourism industry warrants special attention in the Caribbean. The problem of sewage disposal, inherent in most hotels located in the coastal zone, and the resulting pollution, threaten the quality of water in many beaches in the Caribbean. Adequate sanitary infrastructure is therefore needed to sustain the tourism industry.

TREATMENT METHODS:
How They Work

There are two main reasons for wastewater treatment. The first reason for wastewater treatment has to do with the large number of disease-producing organisms in the water. To prevent disease from being passed on or transmitted, wastewater has to be disinfected. The second reason for treating wastewater is to preserve and protect the aquatic environment, marine, freshwater and ground water resources.

Traditional Treatment Methods

If wastewater is discharged into receiving water, the organics in the wastewater can create serious problems, as mentioned above. These organic wastewater solids are a major food source for a number of organisms.

If there are large quantities of organics present, certain types of bacteria will grow and multiply rapidly as long as there is enough dissolved oxygen for them to live.

If the dissolved oxygen level in any part of a watercourse is used up or depleted, (aerobic) bacteria disappears and other (anaerobic) bacteria start to grow. Anaerobic bacteria do not require dissolved oxygen to live, while facultative bacteria can continue functioning under these conditions as well.

This kind of situation produces septic conditions, with associated foul odours, discoloration of the water and dangerous gases. Nature helps to prevent anaerobic conditions by natural re-aeration.

Turbulence or wave action on the water surface captures oxygen from the air. This oxygen dissolves in the water and helps replace that which has already been used up.

The amount of dissolved oxygen present in the receiving water is extremely important, not only in terms of the kind of bacteria that will be active, but also in terms of the plant and animal life that will exist in the water.

As the bacteria consume organic solids, the solids breakdowns are decomposed. Aerobic decomposition makes use of aerobic and facultative bacteria and is a pretty clean operation. There are no foul odours or unsightly conditions produced. However, if there is too much organic material in the water and too many active bacteria, dissolved oxygen may be used up faster than it can be replaced.

When the dissolved oxygen runs out, the aerobic bacteria can no longer live, and the aerobic decomposition process stops. Facultative bacteria however remain active and when there is no dissolved oxygen present, anaerobic bacteria become active.

When anaerobic and facultative bacteria become active, they get energy to meet their needs by decomposing organic and some inorganic solids. This process of decomposition is called anaerobic decomposition. Anaerobic decomposition "rots" the solids in the sewage, producing foul odours and unsightly conditions.

It is much more desirable, then, to have aerobic decomposition occur, rather than anaerobic decomposition.

Knowledge of what happens in the natural purification process is used in the design of wastewater treatment plants. In biological treatment processes, natural sequences in time and space are compressed, and an environment that favours aerobic rather than anaerobic decomposition is provided.

The treatment process that is most like the natural process is called a waste stabilization pond. These ponds hold wastewater. Bacteria eat the organics, and in doing so, lower the oxygen level.

Once the organics have been largely consumed, and natural processes have raised the oxygen level, the water is suitable for discharge. Waste stabilization ponds can be very effective, and are common in locations where large areas of land are available.

When wastewater enters a treatment plant, it is processed first through pretreatment steps. Pre-treatment usually involves screening, grit removal, and shredding. These processes remove the coarse or other unsuitable material from the wastewater before it enters the actual plant. Once the coarser or larger materials are removed, the liquid then goes on to receive primary, or first treatment.

During primary treatment, some of the solids carried by the wastewater will settle out or float to the surface, where it can be separated from the wastewater in a secondary clarifier where they are allowed to settle to the bottom.

Following chlorination or some other form of disinfection after secondary treatment, the liquid is usually clean enough to be let out into the receiving waters.

Sometimes, there may be a third treatment or tertiary treatment stage that the liquid goes through before it is allowed back into the environment. Biological wastewater treatment results in the continual growth of bacteria some of which are regularly removed as sludge.

This sludge is treated and de-watered in the "solids handling" part of the plant. These waste materials removed from the treatment processes go on to different kinds of solids handling facilities before they are finally disposed of.

This then is a very simple picture of the steps that wastewater goes through in a typical wastewater treatment plant. Not all treatment plants are or look the same. But the steps and the way the wastewater is treated is much the same in most plants.

In the Caribbean, the most common scenario is that the tourist resort provides and maintains their own collection and treatment facilities. In fact, half of the wastewater plants in the Caribbean are operated by the tourism sector.

According to studies by the Caribbean Environmental Health Institute, 75% of these plants do not comply with the criteria for good operation, i.e. an effluent quality of 30 mg/l Biochemical Oxygen Demand (BOD) and Suspended Solids (SS) or 85% removal of BOD and SS. A study in 1991 revealed that 75% of the wastewater treatment plants in the Caribbean do not meet effluent criteria of 30 mg/l BOD_5 and 30 mg/L suspended solids. Additionally in 60% of the cases, the effluent is discharged into the aquatic environment (35% are marine and 25% fresh water bodies). (Vlvgman,1992)

The poor operational status is caused by:

a) Application of technologies that require high levels of skilled human resources and energy input in operation and maintenance;
b) Inadequate operating skills with limited understanding of treatment processes and insufficient process monitoring;
c) Insufficient time allocation to operation and maintenance;
d) Insufficient operational support through operation and maintenance contracts;
e) Insufficient funds allocation;
f) Inadequate disposal facilities for excess sludge.

In many hotels, treated wastewater is discharged into the nearshore marine environment, which in most cases are recreational waters. Considering that treatment and disinfection are not adequate, this situation poses serious health risks, as was discussed earlier.

RECOMMENDATIONS FOR THE TOURISM SECTOR

1) Encourage plant operators to pursue training (and support them).
2) Ensure that Operation and Maintenance Manuals are available.
3) Encourage maintenance contracts for the treatment facilities.
4) Reduce wastewater flow (by reducing water use).
5) Re-use treated wastewater where possible (e.g. flushing; irrigation).
6) Improve sludge handling.
7) Restrict disposal of effluent in shallow coastal areas.
8) Use as much as possible locally available equipment.

MODULE 7

METHODS FOR THE TREATMENT AND DISPOSAL OF WASTEWATER

METHODS FOR THE TREATMENT AND DISPOSAL OF WASTEWATER

OBJECTIVES:

- To discuss the importance of treating wastewater - with an emphasis on health and environmental issues.
- To introduce the wastewater treatment technologies which are available in the market place and identify a rationale for selecting suitable technology.
- To discuss the environmental factors which should be considered in selecting a wastewater treatment system .

OVERVIEW:

- Wastewater includes different types of pollutants such as solids, toxic materials, nutrients and pathogens which must be taken into consideration when selecting treatment.
- Other factors to consider when selecting treatment technology include sources, seasonal variations, wastewater flows, environmental standards, environmental setting and cost/benefit issues.
- Treatment process can be classified into primary, secondary, tertiary and advanced wastewater treatment which relate to the effluent quality expected to be produced.

CONSIDERATIONS IN TREATING WASTEWATER

There are many objectives as well as some constraints which need to be considered when selecting appropriate wastewater treatment technologies. These are:

- To ensure that the treatment and disposal of wastewater does not:
  - constitute a hazard to the health of the community
  - give rise to offensive odours (aesthetics)
  - create pressure on the assimilative capacity of the receiving environment (ecology)
- The constraints are related to:
  - the minimum acceptable value wastewater discharge
  - the cost of treatment

Additionally, in selecting the appropriate technology satisfactory answers have to be found to the following questions:

- What does the wastewater contain?
- How can it be treated before it can be safely discharged to the environment?

EFFECTS OF TYPES OF POLLUTANTS

Pollution affects oxygen resources in surface waters in the following ways:

- The discharge of organic materials exerts an oxygen demand as they undergo biodegradation.
- The discharge of reducing agents depletes oxygen resources as they are chemically oxidized.
- The discharge of fats, oils and greases forms surface films which inhibit the transfer of atmospheric oxygen.

Solids - Suspended and Dissolved

- Negative aesthetic effect (turbidity).
- Restrict light penetration which can reduce the range of aquatic life (biodiversity).
- Form solids on stream banks either smothering the bottom organisms (benthic community), change dissolved oxygen levels in bottom waters.

Toxic Materials

- Heavy metals such as found in pesticides can cause fish kills in surface waters.
- Heavy metals can also affect biological treatment processes.
- Toxic effects may be either dramatic (acute toxicity) or long-term accumulative effects (chronic toxicity).

Plant Nutrients

- Enrichment of surface water from plant nutrients causes - eutrophication.

Pathogens

- Main concern relates to health either from contact in recreational uses or consumption in the case of domestic water supplies.

FACTORS TO CONSIDER IN SELECTING WASTEWATER TREATMENT TECHNOLOGY

There are a number of factors which need to be adequately considered before selecting the appropriate treatment technology. These are:

- Wastewater characteristics
  - sources of wastewater
  - chemical composition
  - seasonal variations

- Wastewater flows
  - essential for hydraulic design

- Environmental Standards (regulatory/ mandatory)
  - effluent discharge standards
  - ambient water quality standards

- Environmental Standards (voluntary)
  - International Standards Organisation (ISO) 14000
  - Environmental Management Systems

- Environmental setting (location of property)
  - urban or rural
  - coastal or inland
  - groundwater resources
  - assimilative capacity receiving waters
  - carrying capacity
  - cumulative environmental impacts

- Cost/benefit
  - traditional
  - "geonomics"

- Suppliers/designers

WASTEWATER TREATMENT

Classification of Treatment Processes

Treatments are classified under a number of broad headings generally related to the effluent quality which is expected to be produced. There are four different categories of treatment; (1) Primary Treatment, (2) Secondary Treatment, (3) Tertiary Treatment and (4) Advanced Wastewater Treatment.

The following section describes the components of each type of treatment.

Primary Treatment

- The simpliest form of treatment comprises simple gravity sedimentation, preceded by simple processes such as:
  - screening
  - grit removal
  - sometimes pre-chlorination and pre-aeration

- Removes most identifiable solids and floating matter.

Module 7 - Table 1

Data on Effluent Quality expected from Primary Treatment

Effluent Quality			
Parameters mg/l	Influent	Effluent	% Removal
BOD	300	200	25 - 40
TSS	300	100	50 -70

The main purpose of the preliminary processes is the selective removal of suspended materials which could interfere with the physical operation of the treatment operations and to precondition the wastewater so as to improve treatment efficiency.

Screens

- Screen devices remove rags and other coarse materials and are classified as follows:
  - aperture size (course, medium, fine)
  - configuration (bar, racks, mesh, perforated)
  - cleaning method (manually raked, mechanically raked, water washed)
  - surface movement (fixed, moving, cutting).

- Disposal of Screenings
  - Quantity will vary depending on design.
  - Screening frequently is heavily contaminated with organic matter which attract flies.
  - Must be disposed of as quickly as possible.
  - Disposal methods include incineration, burial, disintegration followed by a return to the flow (cutting screen).
  - Incineration not economical for small operations.
  - Landfill sites with incinerators are an option.

Grit chambers

- removes inorganic grit which may cause abrasion.

Sedimentation

- Removal of solid particles from a suspension by setting under gravity.
  - The major process in primary treatment.
  - Removes 50-70% of suspended solids containing 25-40% BOD.
  - Sedimentation also required where phosphorus removal is carried out by chemical precipitation.

Secondary Treatment

- Removes non-settleable, large organic material.
- Normally some form of aerobic treatment (with oxygen).
- Effluent quality is usually between 15 - 20 mg/l BOD.
- The use of chemical coagulation before primary treatment can reduce BOD further, may be to 60-80% or 50-100 mg/l BOD.

Module 7 - Table 2

Data on Effluent Quality expected from Secondary Treatment

Effluent Quality			
Parameters mg/l	Influent	Effluent	% Removal
BOD	300	15 - 20	90 - 95
TSS	300	30 - 40	80 -85

- Chemical treatment cannot achieve wastewater quality needed for release into inland streams.
- Use biological process for removal of organic matter from wastewater i.e concentrate the natural aerobic biodegradation process into an engineered system.
- Methods of aerobic biological treatment can be:
  - fixed film
  - suspended growth

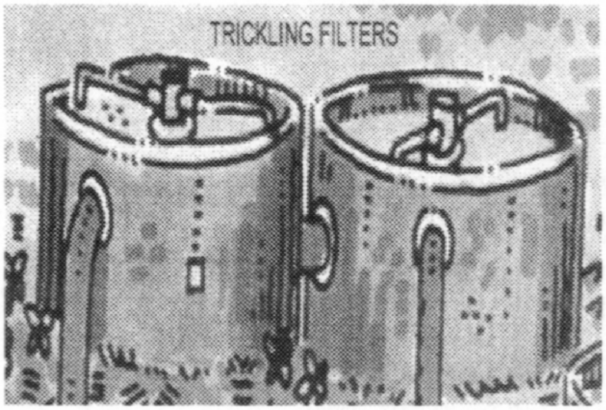
Module 7 - Table 3
Fixed Film

Types of Treatment	
Land Treatment	Oldest method, risk of storm water runoff causing heavy surface water pollution. Number of environmental concerns
Trickling Filter	Consists of bed of media on which bacteria grows. Oxygen supplied to system by air circulating through bed
Rotary Biological Filter	Similar to trickling filter. Biological film grown on solid surface. During rotation contact with atmosphere absorbs oxygen.

Module 7 - Table 4
Suspended Growth Process

Types of System	
Wastewater Stabilisation Ponds	algal growth in released oxygen sludge layer develops at bottom of pond (anaerobic) contributes significantly to pond efficiency degree of effluent quality variable
Aerated Lagoon	Intermediate between waste stabilisation and activated sludge process oxygen supplied artificially higher level of solids kept in suspension (intense aeration) final sedimentation necessary
Activated Sludge	wastewater aerated in presence of flocculated microbial culture (activated sludge)

Trickling filters and activated sludge plants are frequently used in the Caribbean. The section below presents information on the performance of trickling filters and compares it with the activated sludge process.



Performance of Trickling Filters (Advantages & Disadvantages)

- Particularly suited to treat difficult and variable wastewater.
- High proportion of biomass attached to media gives good buffer against variable organic loads.
- Prone to some fly and odour nuisance.
- Area required is about 4 times that needed for Activated Sludge Plant (ASP).
- Capital cost higher than ASP by 10-50%.
- Running costs usually lower - gravity fed plants.
- Require several weeks for useful biomass to be established.
- Very little process control required due to self correcting nature of process.
- The main advantages are:
  - ability to handle shock loads - greater volumes able to be diluted
  - ability to treat biodegradable toxins
  - no sludge recycle necessary
  - in suitable terrain construction consists mainly of cheap earth works.
- The main disadvantages are:
  - more land required for implementation
  - only about 80% maximum BOD efficiency removal

Module 7 - Table 5

Comparison of Activated Sludge and Trickling Filter Plants

Factor	Activated Sludge	Percolating Filter
Capital cost	Low	High
Operating cost	High	Low
Land area	Low	High
Technical control	Much	Little
Climate	Problems in dry summer months	Best at higher temperatures
Industrial waste-waters in sewage	Prone to failure	Not prone to failure
Effluent quality	Low suspended solids; not normally nitrified	Nitrified but prone to high suspended solids
Fly and odour nuisance	Little	Can be considerable
Strong wastewaters	Not suited	Suited
Mechanical equipment	Much	Little
Head loss	Low	High

Methods of Anaerobic Biological Treatment /Anaerobic Ponds

- Heavily loaded open ponds.
- Usually 2-4 m deep.
- Used as pretreatment ponds in municipal and industrial wastewater treatment.
- Serves to reduce organic load applied to aerobic system.
- Odour problem common with this type of pond.

Module - Table 6

Anaerobic (Pre)treatment Domestic Sewage vs. Conventional Aerobic Methods

1. The method is simple in construction and operation, consequently inexpensive.
2. The method generally does not require the supply of electricity.
3. The method can be applied at very small and at very large scales, enabling a decentralized application.
4. Application of anaerobic wastewater treatment, when applied in a decentralized mode, will lead to very significant savings in the investment of sewerage systems.
5. The excess sludge production is low, particularly when expressed in volume, because the thickening characteristics of the sludge are very good.
6. The sludge is well stabilized.

Source: Treatment of Raw Sewage under Tropical Conditions - Scientific Research Council (SRC) training workshop Anaerobic Biological Process Design.

Module 7 - Table 7

Limitations and Drawbacks of Anaerobic Treatment of Domestic Sewage

1. The method cannot accomplish a complete treatment, because merely organic compounds and TSS will be removed.
2. The method is fairly susceptible to the presence of large numbers of chemical compounds (generally no problem for domestic sewage).
3. The application of the method is quite sensitive in lower ambient temperatures.
4. There still is very limited experience at full scale.

Source: Treatment of Raw Sewage under Tropical Conditions - Scientific Research Council (SRC) training workshop Anaerobic Biological Process Design.

Tertiary Treatment

- Effluent polishing and disinfectant process.
- Removal of inorganic colloidal solids, dissolved inorganics solids, pathogenic indicator organisms.
- Maturation ponds provide opportunity for prolonged settling.
- Suspended solids undergo anaerobic degradation.
- Algae do not settle so effluent quality is highly variable.
- Disinfection process for the destruction of pathogenic and bacterial indicator organisms often included in this classification.
- Some types of pollutants remain
  - suspended (particulate) materials (inorganic colloidal solids),
  - dissolved inorganic solids,
  - dissolved inorganic plant material,
  - pathogenic indicator organism.
- Process to remove these are classified as tertiary treatment or advanced wastewater treatment.
- Trying to achieve effluent polishing and disinfection process.

Module 7 - Table 8

Typical Design and Operational Data for Tertiary Ponds Grass Filtration and Land Filtration (1)

Treatment Method	Configuration	Loading Rate m3.m2.d	Average Performance		
			S.S. Removal%	B.O.D. Removal%	Bacterial Removal%
Tertiary Ponds	Depth 1-2m Detention 2-20 days plug flow 2 to 4 ponds in series	<0.15 to 0.5	25-70	30-70	70-95
Grass Filtration	Grass plots - gradient 1:100 preferred 1:60 maximum uniform flow distribution	0.1-0.8	60-80	50-75	89-95
Land Filtration	Grass plots, permeable solid gradient as above. Under-drainage may be provided	<0.1	>80	>75	>95

Maturation Ponds

- Provide opportunity for prolonged setting.
- Suspended solids which settle undergo anaerobic degradation.
- Algae do not settle so effluent quality is highly variable.

Grass Filtration

- As effluent flows through fish growth develops.
- Much of suspended solids content is strained or settled out, later degraded by soil bacteria.
- Grass growth should be moved and disposed of occasionally.

Land Filtration

- Applied to land surfaces at lower rates than in grass filtration.
- Much of the water infiltrates and percolates through the soil toward drainage.
- Some loss to evaporation.

Effluent Disinfection

- Final effluent can be disinfected prior to discharge.
- Major disinfectant - chlorine.
- Disinfection is intended to kill pathogens, to minimize disease transmission.
- Effectiveness of disinfection measured in terms of time and concentration required.
- For chlorine contact time of 30 minutes is usually adequate.
- Chlorination tank designed to ensure effective mixing and 30 minute retention.
- Dose of chlorine depends on the degree of treatment.
- Primary effluent requires a dose of approximately 30 mg/l.
- Secondary effluent requires 10mg/l.
- Not entirely free of adverse effects, can kill or inhibit aquatic life.

Ozonization

- Ozone is a powerful disinfectant.
- Produced by passing an electrical charge through the air.
- Doses are similar to what is needed for chlorine.
- No potentially dangerous chemical formed.
- Breaks down to oxygen.
- Usually more expensive than chlorine.

Removal of plant nutrients also sometimes referred to as 'Advanced Wastewater Treatment' - AWT.

The table 9 below provides some information on the characteristics of various strengths of wastewater.

Module 7 - Table 9:

Comparison of Concentration of Selected Constituents in Municipal Wastewaters

Parameter	Concentration mg/l water strength		
	Strong	Medium	Weak
BOD	300	200	100
TSS	350	200	100
Nitrogen			
- Total	85	40	20
- Organic	35	15	8
- Ammonia	50	25	12
Phosphorus			
- Total	20	10	6
- Organic	5	3	2
- Inorganic	15	7	4

NON-CONVENTIONAL - WETLANDS WASTEWATER TREATMENT

In more recent times wetlands have become a method of treatment of wastewater. Wetlands can be natural or actual e.g. areas where water is the primary factor controlling the environment and the associated plant and animal life constructed.

What is a 'wetland'? - sites which are waterlogged or water covered for significant parts of the year, such as:

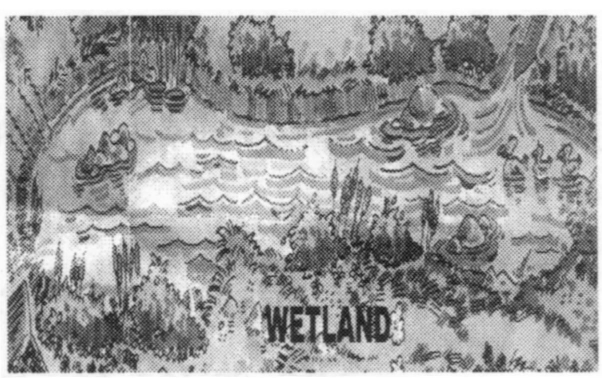
- swamps
- mangroves
- grasslands

Wetlands can be natural or man-made such as fish and shrimp ponds, salt pans and irrigated agriculture land. Some constructed wetlands are systems specifically designed for wastewater treatment. There are various types of constructed wetlands.

Types of Constructed Wetlands

1. Free water surface (FWS) wetland. It contains aquatic vegetation in a relatively shallow bed or channel, and its water surface is exposed to the atmosphere. The FWS is the most common type of constructed wetland in arid areas.

2. Subsurface flow (SF) system. It contains a foot of permeable media such as rock, gravel, sand or soil that support the root



system of the aquatic vegetation. The water level in the bed is maintained below the tap root of the media, which reduces problems of human exposure, animals and odor.

The SF type of systems are most applicable to small scale users.

What goes into designing a constructed wetland?:

In designing a constructed wetland there are four critical parameters which should be taken into consideration. These are:

- retention time
- pathogen removal
- volume wastewater
- desired effluent quality

Module 7 - Table 10

Potential Treatment Efficiency of Wetlands

Parameter	Percent
BOD	50-90
T.S.S.	40-95
Faecal Coliform	80-99
Total Nitrogen	30-90
Total Phosphorus	20-50

- Wetlands wastewater treatment - treated effluent becomes the major water source.
- Wetlands can be used as primary or secondary ponds/treatment.
- Ponds can provide habitat for bird, fish, terrestrial plants.

Wetlands of all parts of natural ecosystems are the most threatened. The cause for progressive, sometimes irreversible degradation of wetlands include eutrophication, from farm, factory and domestic waste, drainage and abstraction, pollution from herbicides, pesticides and industrial effluent.

Package Plant - Some Tips

Package plants are normally associated with a prefabricated unit which is simply connected to the wastewater flow. The definition may be broadened to include systems which are not necessarily prefabricated but pre-engineered for small scale treatment. There are several types of package plants available. These are:

- activated sludge
- extended aeration
- rotating biological contactor (RBF)
- trickling filter

Maintenance of these units should be considered even before installing the unit. Issues such as the location, accessibility etc. need to be fully considered. Some of the factors to be considered are presented in the following checklist:

Location

- Should be kept at maximum practicable distance from existing or proposed residencies.

- Must not be located in areas prone to flooding.
- Trees and other screening vegetation should be left standing where possible.
- Trees should be cleared from around the plant at sufficient distance to prevent leaves and other debris from interfering with unit.
- Potable water supply required.
- Warning signs placed at prominent places.

Daily Attention

- Determine that all pumps, motors, air lifts, and like components are operating properly.
- Visually inspect the appearance of the mixed liquor and final effluent and the rate and appearance of the sludge return.
- Perform routine general 'housekeeping' duties as needed. This often includes hosing down the plant, particularly in splash or spray areas, clean weirs, baffles, scum boards and remove scum, fat grease, fat balls etc., rake screen and dispose of screening.
- Those plants which employ separate settlement require daily squeezing of sludge hoppers to prevent the possibility of bouyant sludge.
- Carry out simple test procedures.

Periodic Attention

- Grease, oil and clean plant components as required.
- Check submerged equipment components, this would include regular surging of air lines to ensure unblocked air supply systems.
- Attend to site, e.g. mow grass, maintain fences.
- Carry out preventative maintenance procedures, including repairs, replacement of worn equipment and parts.
- Waste excess sludge as needed in order to maintain the required concentration of solids in the system.

Process Control

- Routine performance of simple test provides invaluable information about the operation and performance of the plant
- Certain tests require observation
  - flow
  - colour
  - odour
  - settlement
- Other tests
  - pH
  - D.O.
  - BOD
  - T.S.S

DISPOSAL AND REUSE OPTIONS

There are seven possible options for disposal and reuse of effluent. These are:

- Natural evaporation
- Groundwater recharge
- Irrigational uses

- Recreational Lakes
- Municipal Uses
- Industrial Uses
- Discharge into natural waters.
- Outfall.

Natural Evaporation

This method is particularly beneficial where recovery of residue is desirable. The amount of evaporation from the water surface depends on temperature, wind velocity, and humidity.

Irrigational Uses

The use of municipal effluents for irrigation is an acceptable practice, such as in many parts of the United States. Irrigation has been practiced primarily as a substitute for scarce natural waters or sparse rainfall in arid areas. Health regulations govern the types of crops that are irrigated with effluents.

Options for disposal are however dependent on:

- quality of wastewater (stage of treatment)
- quantity of wastewater
- environmental regulations
- environmental setting
- conditions of receiving water bodies.

In designing an irrigation system several factors should be considered:

- Hydraulic loading rate:
  - suitable infiltration and percolation capacity of soil
  - climate
  - vegetation cover.
- Organic loading rate
  - should not exceed 200kg BOD/hectare/week
  - reduced for clayey or sandy soils
  - resting periods.
- Other loading rates
  - nutrients
  - other chemical constituents.
- Land area.
- Storage
  - all land application systems storage required.

It is worth pointing out that a detailed study on local climate, site and wastewater characteristics are needed to design an effective effluent irrigation system.

Outfall

- Usually to the marine environment
- Oceanographic studies required
- An environmental impact assessment (EIA) may also be required
- Distance from shore depends on
  - classification of water
  - energy on coastline

FACTORS TO BE CONSIDERED TO ACHIEVE BEST PRACTICE

A number of factors should be taken into account, with the goals of achieving best environmental practices in the management of wastewater. These can be summerised as:

- Environmental setting (location of property)
  - specially protected waters (marine parks).
  - controlled waters, restricted waters, underground waters.
- Size of property (available space).
- Characteristics of wastewater.
- Local environmental standards.
- Capacity of operators (staff training).
- Opportunities for recovery/reuse.
- Costs/Benefits.

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APPENDIX 1
COURSE EVALUATION

After any form of training course, it is important to determine the relevance and success of the course. The main reasons for doing this are to determine:

- the usefulness of the course to the participants
- the relevance of the content of the course to participants' work
- the adequacy of the level of organization
- the comfort of the facilities
- the clarity of audio-visual material
- the accuracy of the information , and
- the quality of presentations and preparedness of the speakers in terms of their relative expertise

A course evaluation will help determine whether the course was as useful as was expected by the organizers, and if not, will assist in improving on future courses by addressing particular issues that were reflected on negatively by the participants.

Course evaluation sheets are best presented at the beginning of the workshop with the introductory material so that participants have time to read it through and answer questions or make notes as the workshop proceeds. It is best to arrange a box or file for the participants to leave their questionnaires at the end of the workshop, rather than requesting that they be sent by mail or fax on a later date. Participants should be given the option of signing or completing evaluations anonymously.

The design of the evaluation sheet should be simple and straight forward with direct questions that require straight forward answers. The questions should be designed so that answers can be:

1. yes or no
2. not applicable (N/A)
3. on a scale of 1 through to 5, with 1 being the lowest score
4. on a range of opinions - strongly agree, agree, disagree, strongly disagree
5. too short, just right, too long

The questionnaire can be designed to ask all types of questions which give answers in all or some of the categories above. The type of response presented is dependent on the type of question asked and how much information you as the questionnaire evaluator require.

For example the phrase **'The course length was appropriate'** is best served by the answer

1. Too long 2. Too short 3. Just right

rather than

1. Strongly agree 2. Agree 3. Disagree 4. Strongly disagree 5. N/A

At the end of the questionnaire it is useful to leave at least one-half a page for participants to write their own input which can be requested as:

- Comments
- Observations
- Suggestions

If an assessment of presenters is necessary for your feedback this can be included and the presenters can be identified by:

- name
- topic
- time slot

An example of how the questionnaire or evaluation sheet can be organized, and examples of types of questions is given below:

Section 1: Logistics

The advanced mailing gave adequate information to the participants:
1. Strongly agree 2. Agree 3. Disagree 4. Strongly disagree 5. N/A

Section 2: Course content

The course was well organized
1. Strongly agree 2. Agree 3. Disagree 4. Strongly disagree 5. N/A

The stated objectives were met
1. Strongly agree 2. Agree 3. Disagree 4. Strongly disagree 5. N/A

Section 3: General Overview

How valuable did you find the course?
1 2 3 4 5

The presentations were
1. Too long 2. The right length 3. Too short

Section 4: Results

Did the course provide solutions to existing problems?
1 2 3 4 5

Was the schedule of activities clear?
1 2 3 4 5

Section 5: Scheduling facilities

The time of year selected was appropriate
1 2 3 4 5

The refreshments were satisfactory
1 2 3 4 5

The audio-visual materials were appropriate
1. Strongly agree 2. Agree 3. Disagree 4. Strongly disagree 5. N/A

The course length was
1. Too long 2. Too short 3. The right length

Section 6: Observations

1. How will you utilize the information that you have acquired?

2. What were the weak points of the course?

3. What were the strong points of the course?

Assessment of the evaluation sheets or questionnaires can be done by a general review of the answers and comments or can be more detailed by collating all the responses to each question individually and reporting the results as a percentage of the total participants. The latter form is far more useful as statistical analysis can be performed on the data generated and the success of the course can be quantified as well as qualified. If proceedings or other document is produced from the course a copy of the questionnaire should be included as well as statistical or graphical representation of the participants' answers and comments.

This information may also be useful as a tool in obtaining support from funding agencies and relevant stakeholders for the convening of similar training courses.

APPENDIX 2
FIELD AND PRACTICAL EXERCISES

FIELD AND PRACTICAL EXERCISES

Field exercises are important in the understanding of Solid Waste & Wastwater Management and the application of best management practices. Field exercises should be coupled with classroom lectures and included in programme of training courses. The purpose of doing a field exercise is to learn how to plan a field visit, to assess a site and its resources, to look at the impact of a particular activity on the site and on the resources (both negative and positive impacts), to look at possible solutions to potential problems, and to generate discussion on the best approach to waste management. The following points should be taken into account when planning a field exercise.

Site Visit

- Contact appropriate local resource people for involvement and support.
- Tour of a selected area (e.g. fishing village, beach, hotel) and outline objectives of the visit.
- Length of time for field visit and logistic requirements.
- Selection of concepts and practices for discussion or questions to be answered.
- Preparation of a written report after the trip by participants.
- Inclusion of additional material (photographs, references, results of interviews).

PRACTICAL EXERCISES

To facilitate an understanding of Waste Management principles and their practical application, group exercises may also be designed and delivered during training courses. These should estimate discussion and provide a venue to experience some of the issues and challenges faced by different stake holders in the development of sustainable tourism in the Wider Caribbean Region.

In conjunction with the practical exercise, supporting material should be provided. These could include a description of the site, description of the property, map of the area, photographs of the area (including aerial views), copies of existing relevant legislation, (e.g. water quality and effluent standards) and copies of relevant workbooks or manuals for reference.

OTHER PRACTICAL TOOLS

In addition to field and practical exercises, it would be recommended to organize informal discussions with relevant tourism practitioners (staff from tourism boards, development companies and hotels) and environmental bodies from the host country where the course is being held. These should be valuable opportunities for participants and practitioners from different disciplines to interact regarding tourism and waste management.

Another useful tool for the sharing of knowledge and experiences is to invite participants to make brief presentations on the status of tourism development and waste management issues from their own perspectives, or any other case study they judge relevant to the course objectives. Both activities above could be organized as part of an evening programme during course delivery, should time be a constraint.

APPENDIX 3
FIGURES AND PHOTO CREDITS

COVER	-	Three Photographs	-	Environmental Solutions Limited
MODULE 1				
Page 5	-	Coral Reef (photo)	-	Graphic + (Corel Draw Clip Art)
Page 6	-	Silhouette of Bird	-	Graphic + (Corel Draw Clip Art)
Page 6	-	Ocean View (photo)	-	Graphic + (Corel Draw Clip Art)
MODULE 2				
Page 16	-	Various Fish	-	Graphic + (Corel Draw Clip Art)
Page 19	-	Oil Rig	-	Graphic + (Corel Draw Clip Art)
Page 19	-	Birds covered in oil from tanker	-	Graphic + (Corel Draw Clip Art)
Page 20	-	Pollution of Seashore	-	Caribbean Environmental Health Institute (CEHI)
Page 21	-	Coal Mining	-	Graphic + (Corel Draw Clip Art)
MODULE 4				
Page 37	-	Four Clipart showing different aspects of pollution.	-	Graphic + (Corel Draw Clip Art)
Page 43	-	Recycle logo	-	Graphic + (Corel Draw Clip Art)
MODULE 6				
Page 57	-	Pollution of River	-	Graphic + (Corel Draw Clip Art)
Page 60	-	Corel Reef (photo)	-	Caribbean Environmental Health Institute (CEHI)
MODULE 7				
Page 69	-	Septic Tank (illustration)	-	Caribbean Environmental Health Institute (CEHI)
Page 70	-	Tricking Filters (illustration)	-	Caribbean Environmental Health Institute (CEHI)
Page 75	-	Wetland (illustration)	-	Caribbean Environmental Health Institute (CEHI)
Page 76	-	Package Plant (photo)	-	Caribbean Environmental Health Institute (CEHI)